## AGS Studies Report

Date(s) __June 5, 1987__          Time(s) __0800 – 2400__

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Subject    __Gamma–Transition Studies__

### Observations and Conclusion

We were able to successfully jump transition in the AGS with good bunch structure and $< 1/2\%$ losses ($\sim \times 10$ improvement from normal operation) at an intensity of $1.2 \times 10^{13}$ circulating protons. Figures 1, 2, and 3 show the bunch movement in going through transition.

To achieve this, the present ring horizontal high field quads were reconnected to form three doublets ($A^+C^-$, $E^+G^-$, $I^+K^-$) with 3 $\lambda/2$ separation and a new special blowout circuit was built to give a fast decay time. Figure 4 shows the design value of the current pulse with a 60 msec rise time and a 4 msec decay time obtained from the normal Acme power supply. Figures 5 and 6 show the oscilloscope traces of the current pulse and the time at which the transition phase was jumped. If the magnetic field slope is the same as the current decay slope, we would have a $\Delta\gamma_{tr} = 1.9/msec$ as shown in Figure 7. This gives an enhancement factor of 32 over the normal $\dot{\gamma} = 0.06/msec$ and would theoretically give lossless transition passage at $2.0 \times 10^{13}$ protons. The addition of a high frequency rf cavity to increase the bunch area can raise this limit by a factor of 2–3 (Accelerator Division Technical Note No. 265).

The beam quality after transition looks good and we made the following comparison with IPM scans which show an apparent 20% smaller emittance than in the normal accelerator. This smaller bunch size also results in the onset of "bunch tearing" and will probably require the high frequency cavity to compensate for it. The $\varepsilon_H$ values given in Table I are derived from the measured horizontal beam size and includes both the inherent transverse emtitance and the transverse spread resulting from the momentum spread in the beam.

## TABLE I

### IPM Runs

| Condition | Normal Machine | $\gamma_{tr}$ Test Jump |
|---|---|---|
| Q | $7 \times 10^{12}$ | $12 \times 10^{12}$ |
| $\varepsilon_H$ 100 msec | 31.8 | 28.9 |
| $\varepsilon_H$ 400 msec | 79.5 | 59.2 |
| $\varepsilon_V$ 100 msec | 21.3 | 19.3 |
| $\varepsilon_V$ 400 msec | 45.3 | 30.7 |
| $R \dfrac{(\varepsilon_H + \varepsilon_V)\ 400}{(\varepsilon_H + \varepsilon_V)\ 100}$ | 2.40 | 1.86 |
| Date | 1/14/87 | 6/5/87 |

The PUE system was used to check the available aperture and we found that after transition we could move the beam from −0.703 cm to + 0.623 cm without beam loss.

We also measured $\gamma_{tr}$ to check the model calculation from "MAD" W$^+$ case (Table III). The following describes the measurement method. The results in Table II lead us to believe that the model works reasonably well and that we are achieving the predicted behavior.

## Acknowledgments

Thanks to J. Post's group for quadrupole reconnections with no polarity errors and to A. Feltman, J. Funaro, and L. Mazarakis for a blow-out circuit that gave us 10,000 pulses with not a single miss and achieved our design criteria.

## Measurement of $\gamma_{tr}$

$$\gamma_{tr}^2 = \gamma^2 \left(1 + \frac{R}{f}\frac{\Delta f}{\Delta R}\right)$$

1.  R known $\rightarrow$ 12845.3 cm @ quad centers
    $\langle r \rangle_{PUE} = -0.4$ cm)

2.  $\gamma$ from measuring Gauss clock count (= g)

    $p = 0.075 + 5.05 \times 10^{-4} \times g = \beta\gamma m$ $\left[GeV/c\right]$

3.  $\beta$ from $f_{rf}/f_\infty$     $f_\infty$ from R (see 1)     ($f_\infty$ is rf frequency for particles traveling at the speed of light, i.e., $\beta = 1$)

4.  $\frac{\Delta f}{\Delta R}$ from radial scan, using $\langle PUE \rangle$ to get $\Delta R$, rf frequency to get $\Delta f$, correct for $\Delta R_{actual} = 1.2 \ (\Delta R)_{PUE}$

See figures of $\Delta f$ vs. r   (Figures 8, 9) and tables (Table II) of results.

## TABLE II

| Gauss Clock | 12900 | 15900 | 21900 | 28700 | |
|---|---|---|---|---|---|
| Pulse | Off | 1/2 Value | Off | On (10 V) | Off |
| $\Delta f/\Delta r)_{corr}^{cm^{-1}}$ | 149±12 | 176±17 | −178±8 | −150±12 | −256±8 |
| $f_{rf} \times 10^6$ Hz | 4.41306 | 4.42788 | 4.44165 | 4.44816 | |
| $\gamma$ | 7.1 | 8.62 | 11.91 | 15.56 | |
| P GeV/c | 6.59 | 8.03 | 11.14 | 14.57 | |
| $\beta$ | 0.990 | 0.9934 | 0.9965 | 0.9979 | |
| $\gamma_{tr}$ | 8.50±0.1 | 9.52±0.2 | 8.3±0.2 | 11.4±0.3 | 7.95±0.4 |
| $\gamma_{tr}$(model + current trace) | 8.45 | 9.22±0.3 | 8.45 | 11.4±0.2 | 8.45 |

TABLE III

CONFIGURATION: W+
        At Locations "17": (B D), (F H), (J L)
                           (A c)   (E G)   (I K)

| Strength, W | Horiz. Tune | Vert. Tune | Gamma-tr |
|---|---|---|---|
| .10 | 8.679 | 8.779 | 8.694 |
| .20 | 8.655 | 8.775 | 9.485 |
| .30 | 8.617 | 8.769 | 10.788 |
| .40 | 8.569 | 8.760 | 12.637 |
| .45 | 8.542 | 8.755 | 13.801 |
| .50 | 8.513 | 8.750 | 15.162 |
| .55 | 8.482 | 8.744 | 16.771 |

CONFIGURATION: W+
        At Locations "5": (B D), (F H), (J L)
                          (A c)   (E G)   (I K)

| Strength, W | Horiz. Tune | Vert. Tune | Gamma-tr |
|---|---|---|---|
| .10 | 8.678 | 8.779 | 8.713 |
| .20 | 8.654 | 8.775 | 9.568 |
| .30 | 8.617 | 8.769 | 11.016 |
| .40 | 8.569 | 8.760 | 13.165 |
| .45 | 8.541 | 8.755 | 14.589 |
| .50 | 8.512 | 8.750 | 16.340 |
| .55 | 8.480 | 8.744 | 18.552 |
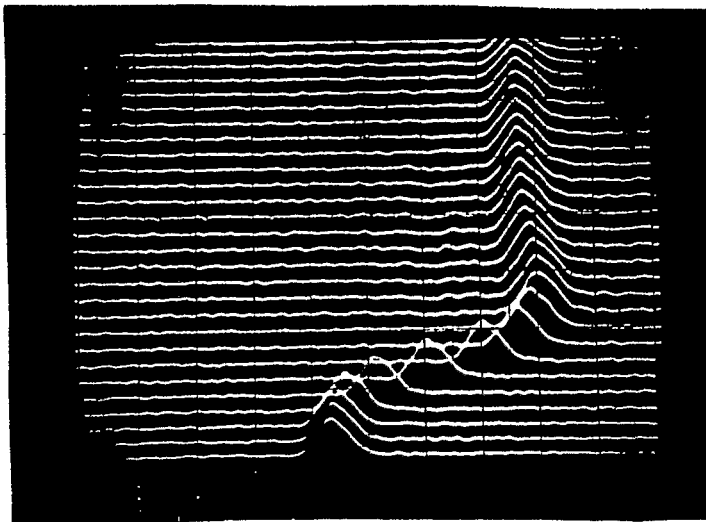
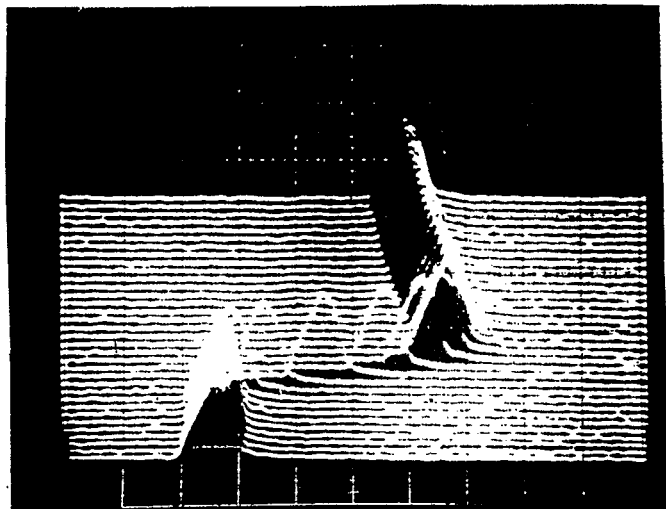Fig. 1.  1.2 x 10$^{13}$ every other turn
20 nsec/box.



Fig. 2.  1.2 x 10$^{13}$ every turn
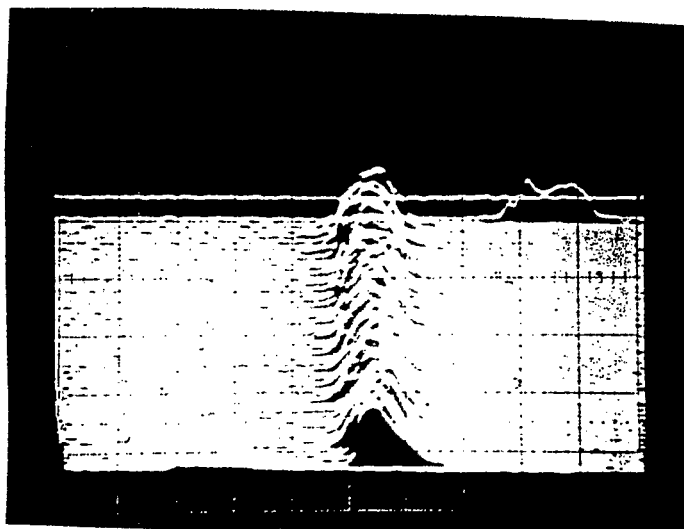20 nsec/box.



Fig. 3.  The 100 msec after transition show-
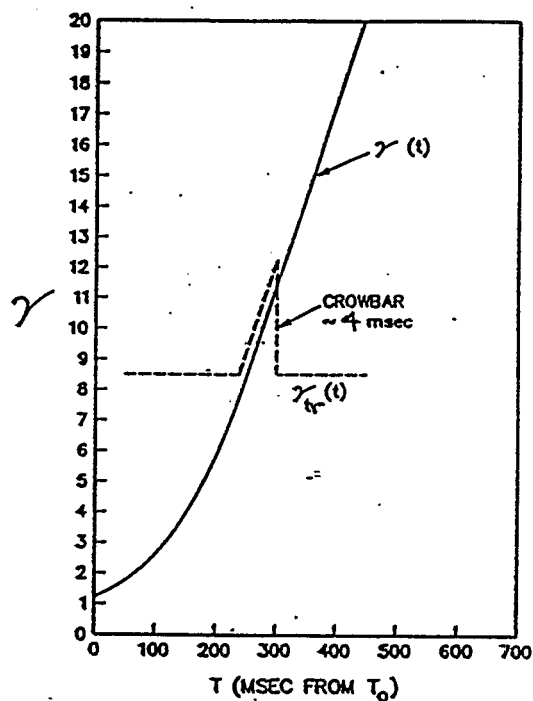ing very little growth
20 nsec/box.



Fig. 4.  Quadrupole pulse for
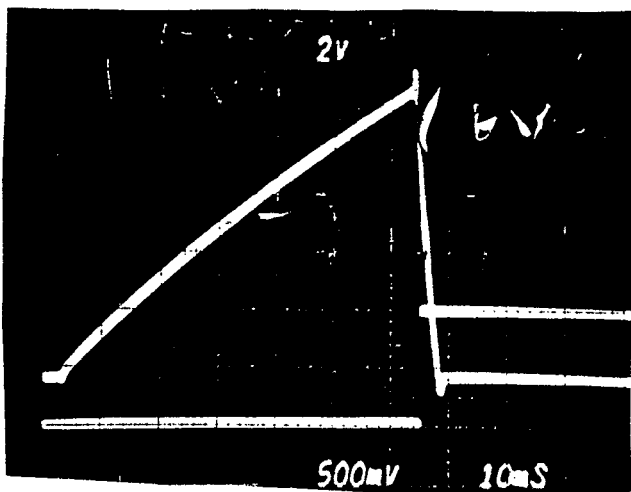altering $\gamma_{tr}$ in rela-
tion to the AGS cycle.

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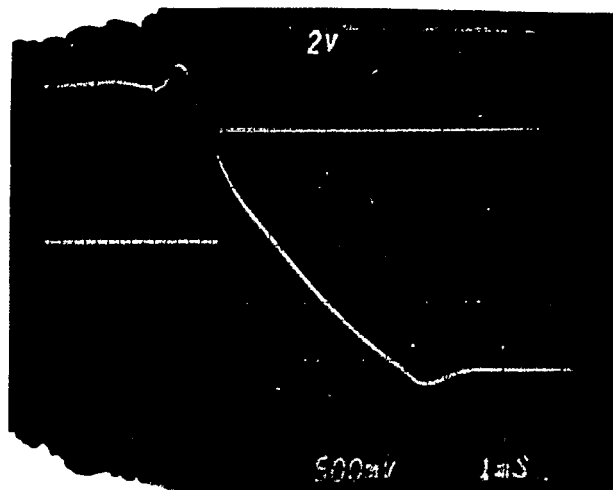Fig. 5. Quadrupole current pulse and
φ jump signals
10 msec/box.

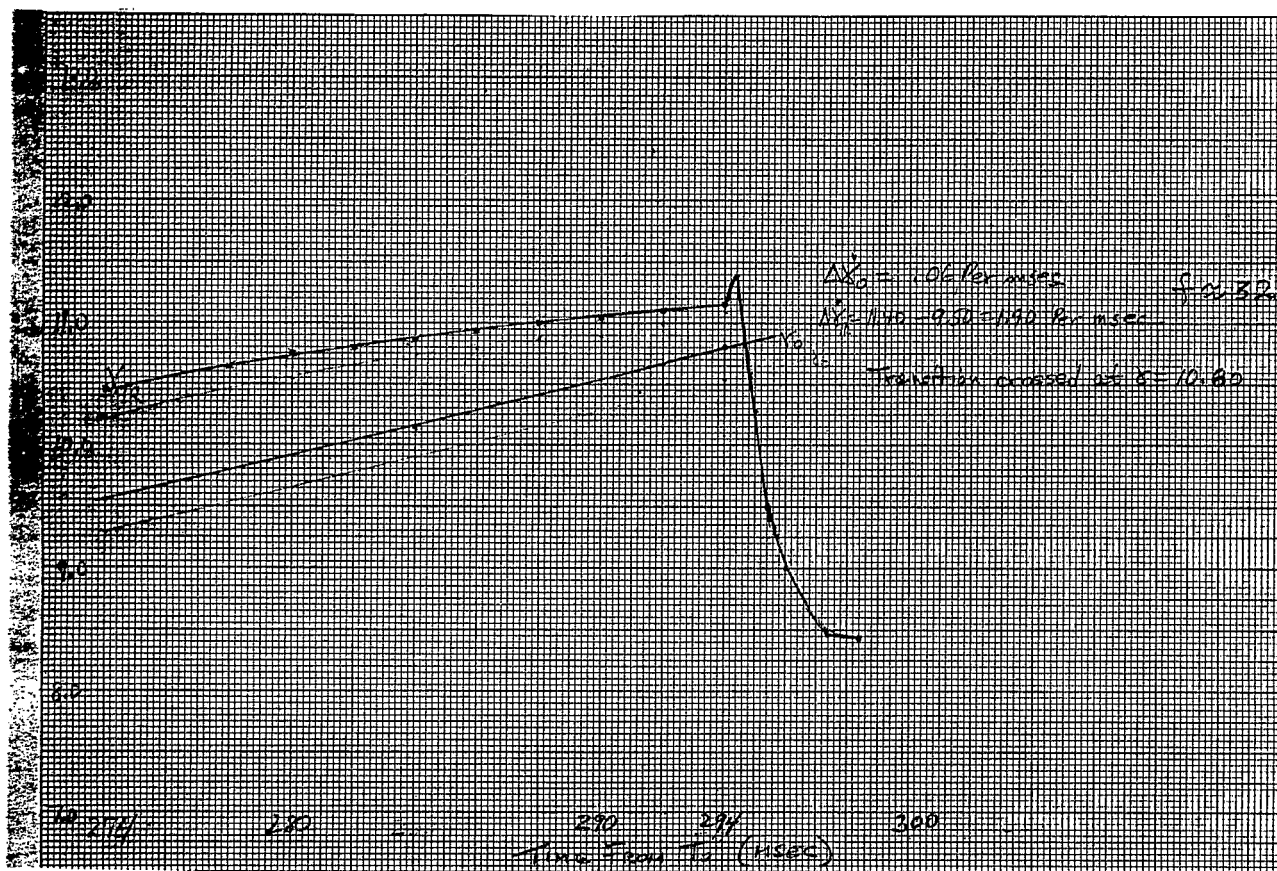Fig. 6. Quadrupole current pulse
and φ jump signal
1 msec/box.



Fig. 7. Quadrupole current pulse converted to $\gamma_{tr}$ from model and $\gamma_o$ showing
transition passage at $\gamma = 10.80$ compared to normal 8.45.

Figures 8 and 9 – for calculation of $\gamma_{tr}$.